Influence of the out-of-band light absorption on temperature increase of a pellicle in EUVL

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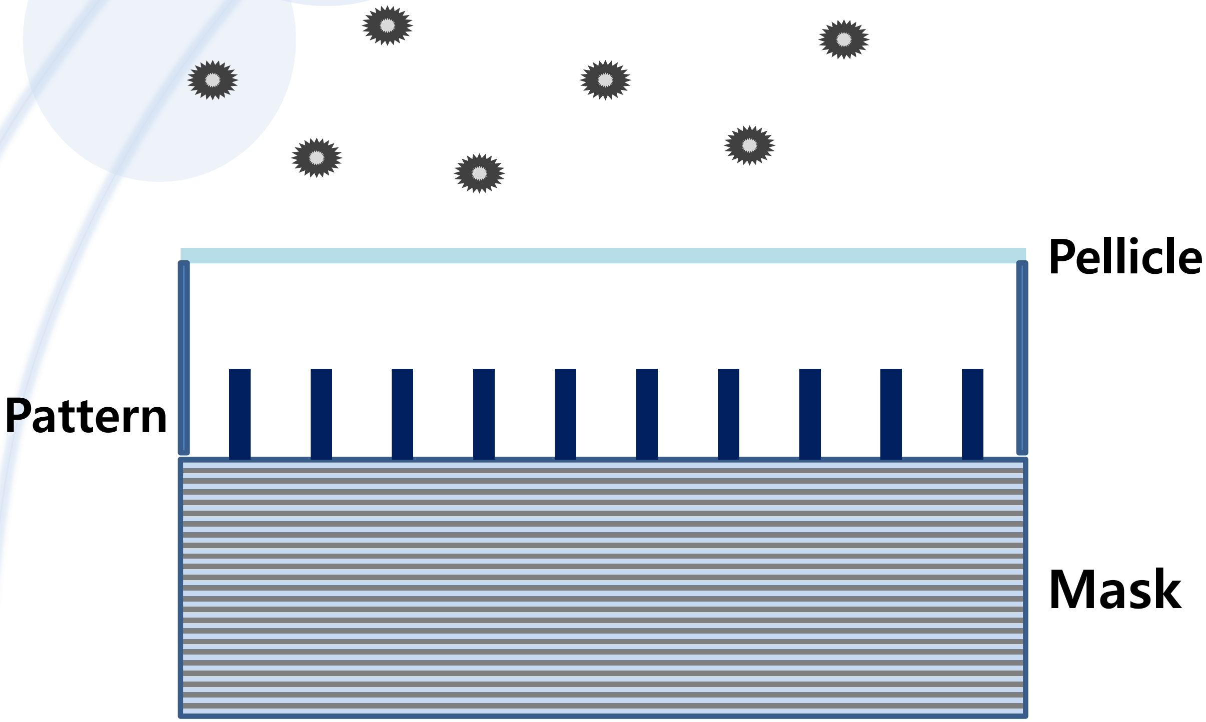
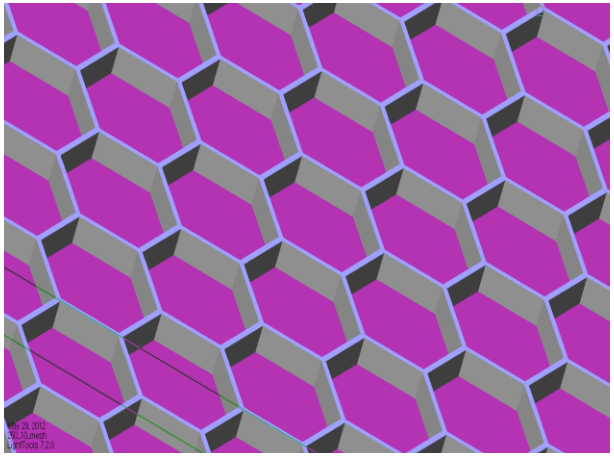
What is the pellicle?

- **Pellicle** : Thin film supported by the mesh structure



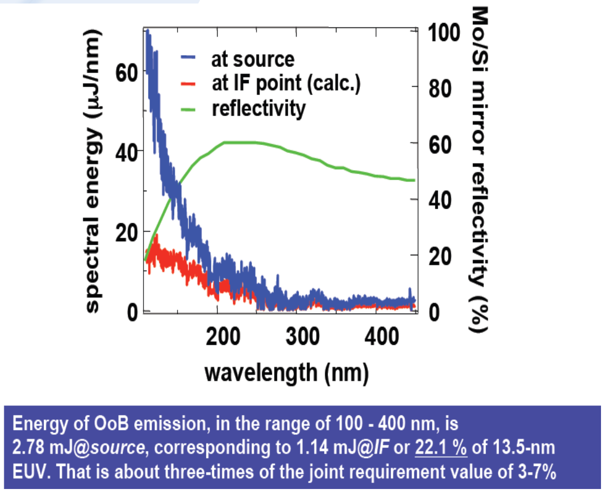


Film + Mesh

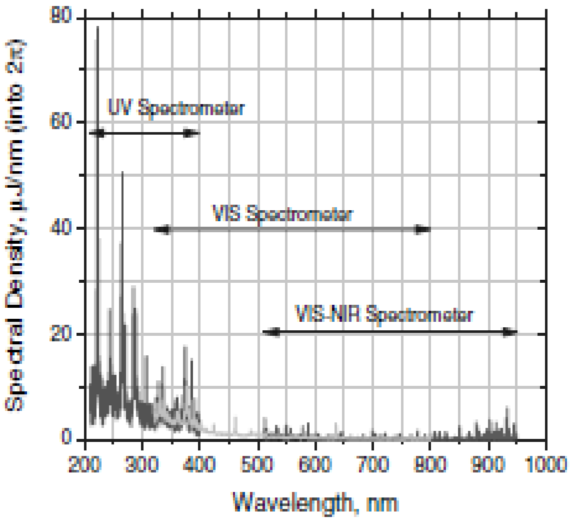
A pellicle protects the mask from contamination!

Additional OoB Radiation

➤ **Out-of-band light spectrum of the EUV source**



<H. Nishimura et al.(ILE Osaka Univ.), EUVL symposium, Sapporo (2007)>



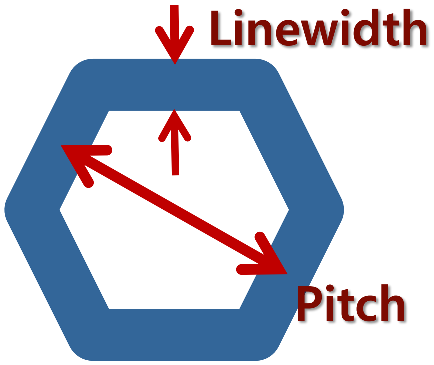
< Igor V. Fomenkov et al.(Cymer,) SPIE 021110 (2012) >

Performance indicator	Specification (production tool)
Maximum IR load into scanner	1% of EUV power in the wafer level
Maximum DUV load into scanner	10-100% of EUV power in the wafer level

< Roel Moors et al. (ASML), SPIE 021102 (2012) >

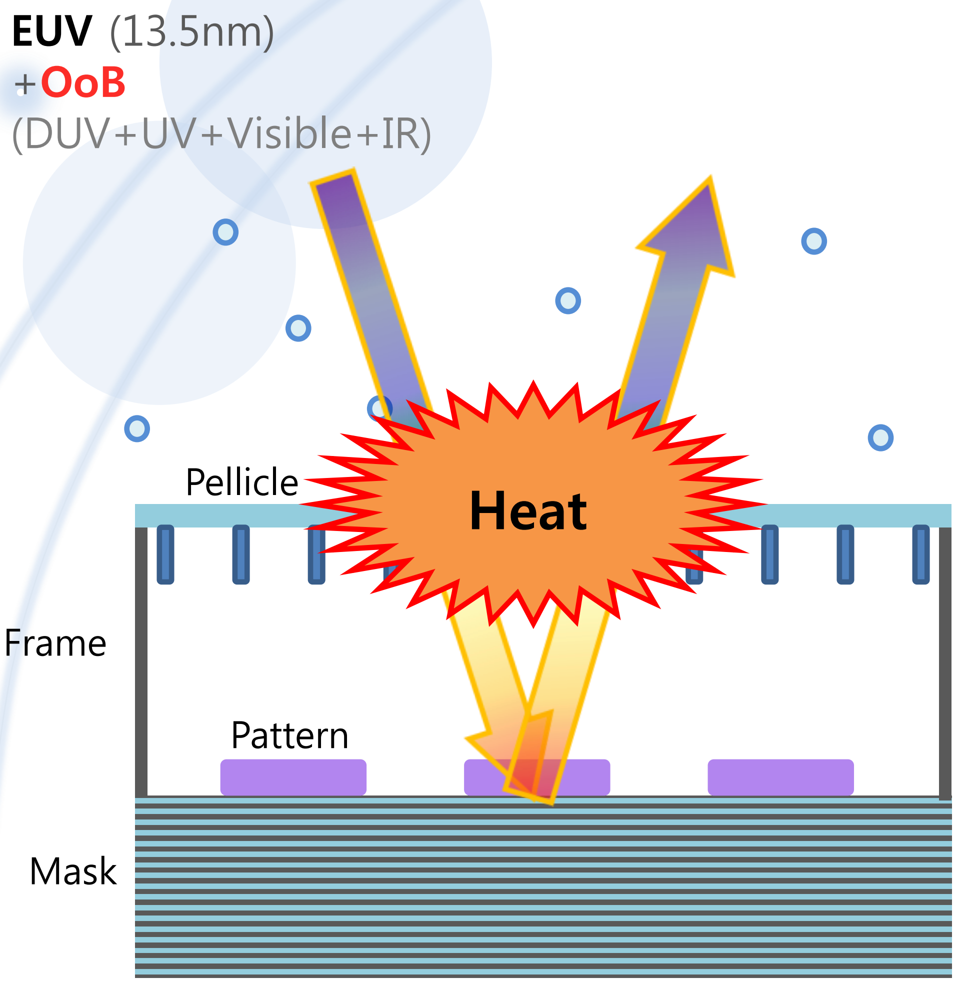
Thermal Modeling

- **Appearance conditions of the pellicle**
  - **Film** : 50 nm thickness
  - **Mesh** : 50 μm thickness,
    3 μm linewidth,
    100 μm pitch



< Mesh >

Thermal Modeling



➤ **Exposure conditions**

Exposure slit area	10 cm^2
Exposure slit time	10 ms
EUV power	50 W
OoB ratio (% of EUV power)	0 – 100 %

➤ **Absorption ratio of the pellicle**

	Film	**Mesh**
EUV (13.5nm)	8%	100%
OoB (DUV~IR)	100%	100%

Thermal Modeling

➢ **Consider radiation cooling in heating process**

$$c \cdot m \cdot \frac{dT}{dt} = \underbrace{\alpha \cdot P}_{} - \underbrace{\varepsilon \cdot \sigma \cdot A(T^4 - T_s{}^4)}_{}$$

heating term due to absorption of EUV beam

cooling term due to heat transfer of radiation mechanism

α : Absorption ratio
ε : Emissivity
σ : Stefan's constant
c : Specific heat

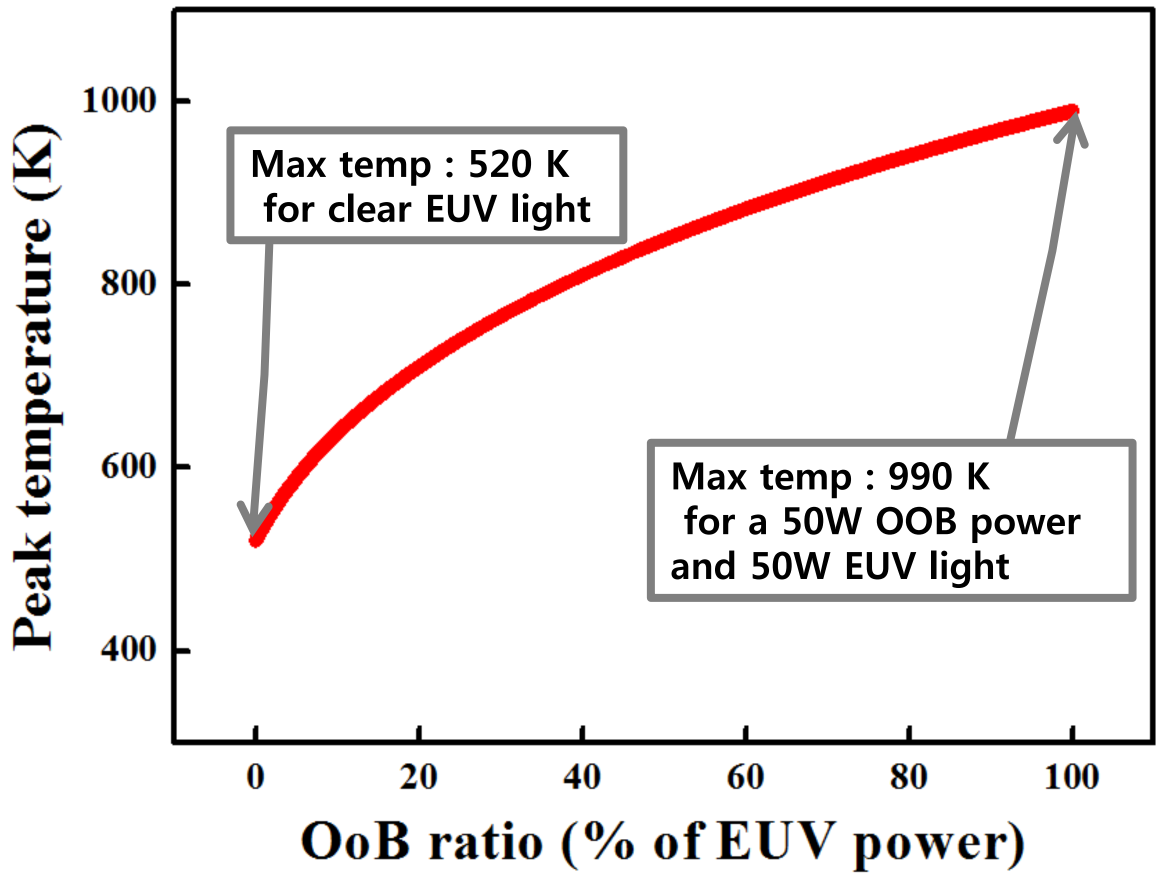
m : Mass
A : Area of a surface of material
T : Temperature of material
$\boldsymbol{T_s}$: Surrounding temperature

※ The dominant cooling process is radiation since :

- Conduction : too small cross-section area
- Convection : vacuum

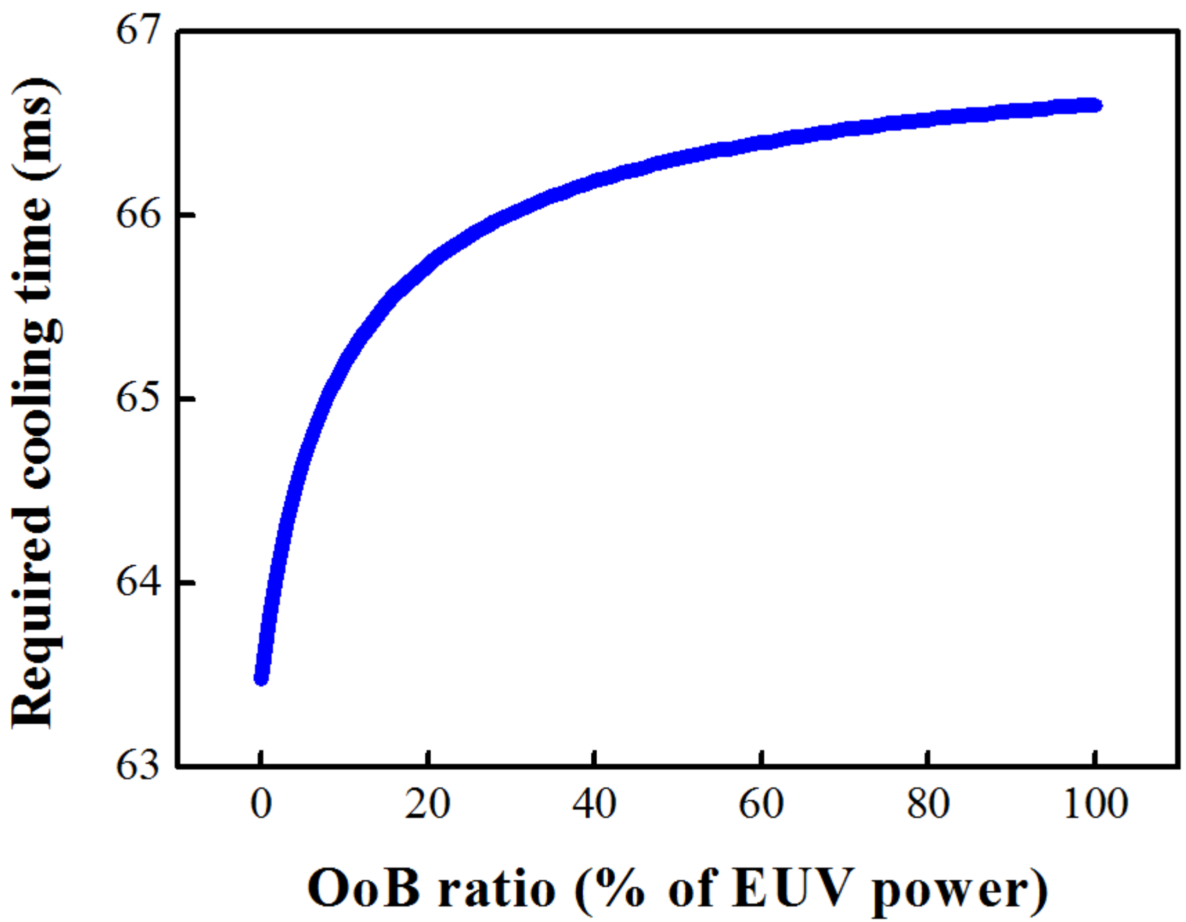
Result – Film

➤ The peak temperature of the film as a function of the OoB radiation ratio.



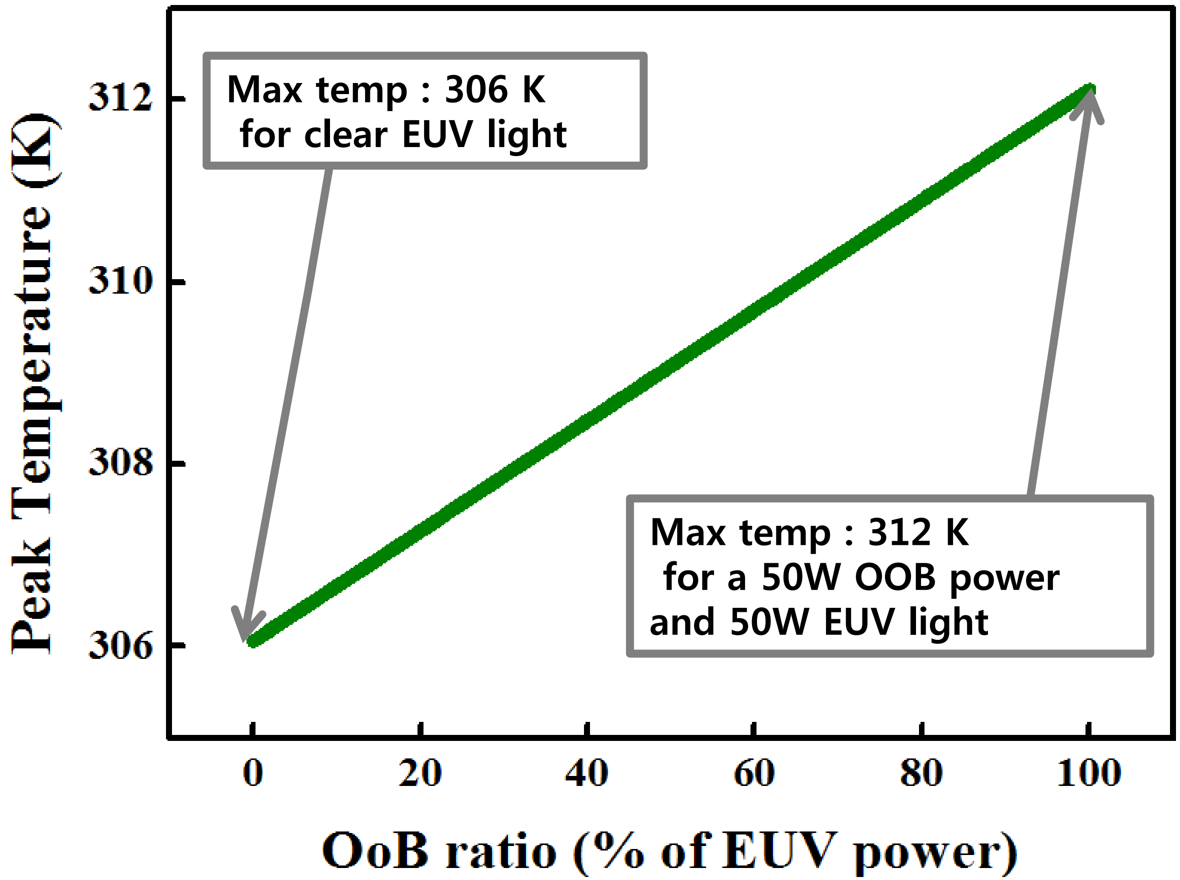
Result – Film

➤Required cooling time of the film as a function of the OoB radiation ratio.



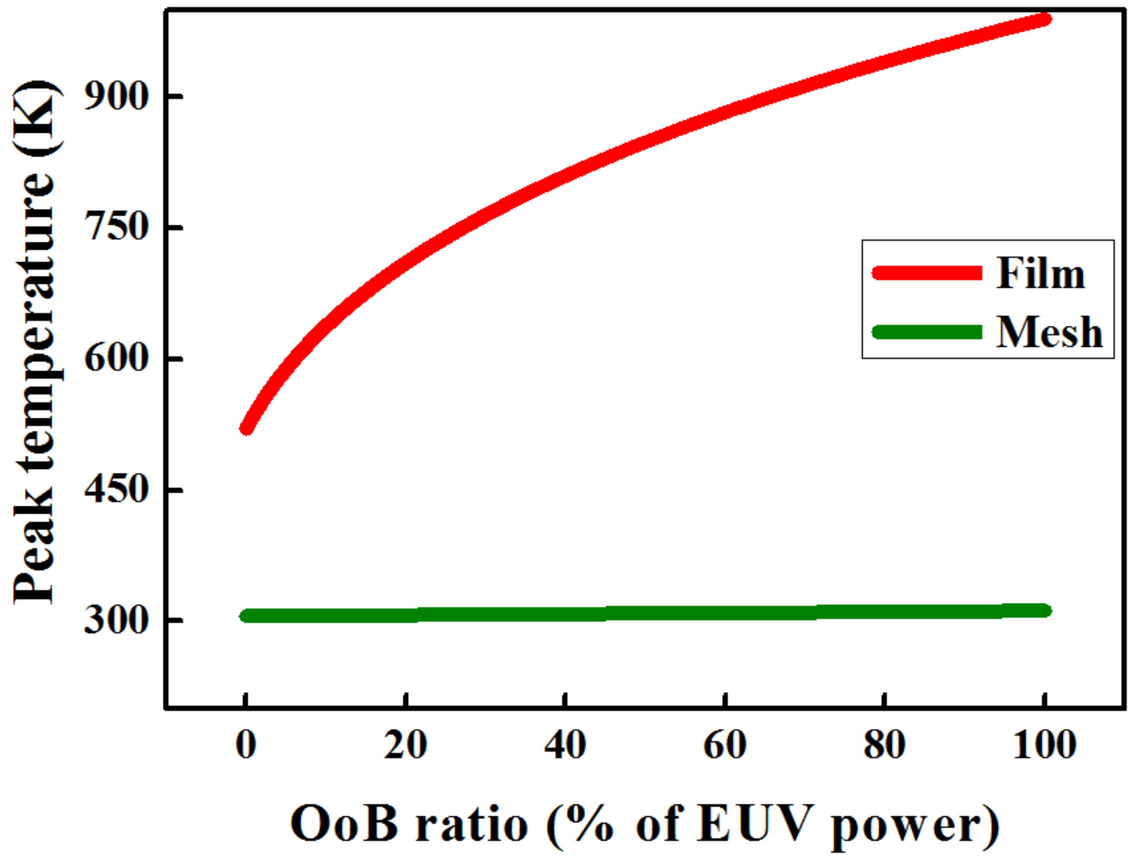
Result – Mesh

➤The peak temperature of the mesh as a function of the OoB radiation ratio.



Result – Mesh

➤ Comparison of the peak temperature between the film and the mesh for additional OoB light absorption.



Conclusion

➢ Thermal behavior of the pellicle was calculated using the modified heat transfer equation.

➢ For 50 W of the OoB incident power and 50 W of the EUV light power, the highest temperature of the film is 990 K which is 470 K higher than that for 50 W of EUV light power only, and the required cooling time is less than 67 ms which is similar to that without EUV. Our results suggest that the thermal problem due to the EUV light even with the additional OoB light absorption can be minimized if the interval between EUV light exposures is longer than 70 ms.

➢ The peak temperature of the mesh is linearly proportional to additional OoB radiation but it was much smaller than the peak temperature of the film. Therefore the thermal problems of the mesh can be neglected.

➢ The temperature difference between the film and the mesh may induce another problems, e.g. pellicle deformation. Therefore it needs more study about the impact of the temperature difference on the pellicle.